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# The X-Ray Source Application (XRSA) Test Cassette for Radiation Exposures at the OMEGA Laser<sup>a)</sup>

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We have designed a sample cassette that can be used to position up to six samples in the OMEGA laser chamber. The cassette has been designed to accommodate round and square samples, both of which can be up to 0.5" thick. The round samples can be up to 1.5" in diameter, and spacers have been designed to keep smaller specimens centered in the sample-receptacle aperture. The test cassette allows each sample to have a unique filter scheme, with multiple filter regions in front of each sample. This paper will present mechanical design considerations and operational aspects of the XRSA cassette.

## I. INTRODUCTION

There are many reasons why one would want to expose a sample to x radiation. One may be interested in measuring peak stresses generated or total impulse delivered to different materials in response to x-ray deposition at different depths, or one may be interested in evaluating the survivability of thin films to ablation or x-ray heating. If one has a robust substrate, one may wish to collect particles and debris from targets used to create x-ray environments. In support of experiments like these, we have designed the X-Ray Source Application (XRSA) cassette for use at the OMEGA laser.<sup>1,2</sup>

During the previous decade, there has been significant activity developing high-flux, high-fluence x-ray sources<sup>3-8</sup> at the OMEGA laser. In all the examples referenced, the cylindrical<sup>5,6,8</sup> or planar<sup>3,4</sup> nature of the target and the geometrical arrangement of the OMEGA laser beams results in a preferred axis for the target orientation, which means that there is limited symmetry for x-ray exposures in orientations orthogonal to the x-ray source's target axis. Further, the material that makes the target itself, usually a shell of low-Z material several 10's to 100's of micrometers thick creates anisotropy in x-ray emission for the lowest-energy x rays. In order to qualify fully the environment produced by the source we need to understand both the uniformity of the x-ray emission from the source at different positions in the test chamber and the debris that the source may produce. With this in mind, we have fielded the XRSA cassette on a series of recent shots in order to characterize the uniformity of the x-ray dose received at each of the six sample positions in the cassette.<sup>9</sup>

## II. DESIGN AND ALIGNMENT

The XRSA cassette has been designed to place six samples

at a distance as close as 19 cm to the OMEGA target chamber center (TCC). A CAD model of the cassette with a pointer for precision alignment is shown in Fig. 1; the actual cassette (the round plate in Fig. 1) as well as the rails (purple frame in Fig. 1) that mount the cassette to any of the six OMEGA diagnostic instrument manipulators (TIMs) are made of aluminum 6061 alloy. The whole assembly shown in Fig. 1 weighs 6.2 pounds. The assembly is positioned in the OMEGA target chamber by the use of a removable point and a ruby-tipped stylus (also shown in Fig. 1). The pointer is used to precisely position the cassette with respect to TCC before each shot campaign.

Before a laser shot, the XRSA cassette is precisely located in the OMEGA chamber. A typical x-ray exposure experiment will use 40 of the 60 OMEGA beams, each of which will have energy up to 500 J in a 1 ns pulse. It is essential to locate the cassette in the OMEGA chamber such that it does not interfere with any of the laser beams propagating to the target at TCC. This is accomplished by first checking the CAD model of the

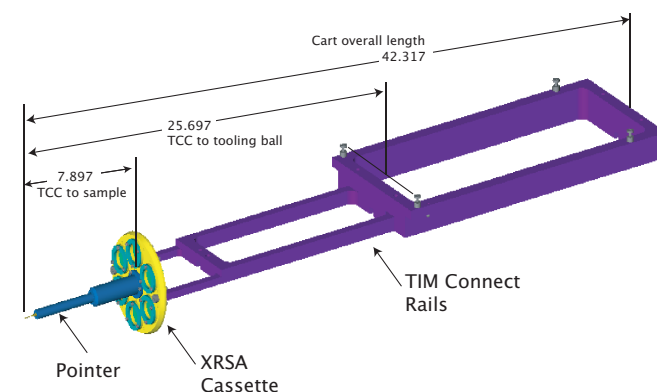


FIG. 1. (color online) The XRSA cassette mounts on aluminum rails to the OMEGA TIM, which allows for precise positioning of the samples with respect to the X-ray source at target-chamber center. Dimensions shown are in cm.

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XRSA cassette in the target chamber with all beams planned for a given experiment pointed to their desired location. Operational protocol at OMEGA requires 0.5 mm clearance between any beam and the edge of a diagnostic instrument, this limits the distance of closest approach we can achieve with respect to the x-ray source. When the CAD model check is complete, and a safe-



FIG. 2. (color online) Photograph of the cassette and mounting rails after being assembled and cleaned. The 2 mm diameter ruby ball at the tip of the stylus, and the chamfered edge of the XRSA cassette are visible in the image.

operating position consistent with the required fluence onto the test specimens is identified, the cassette is precision pointed using a pointer and ruby stylus shown in Fig. 2. The stylus is a standard 20 mm long coordinate measuring machine (CMM) probe with a 2 mm diameter ruby ball at the tip.

The ruby ball at the tip of the stylus is located at TCC using two narrow-field-of-view, high-resolution cameras with orthogonal lines of sight, and the exact coordinates of a reference position on the TIM are saved. The process is repeated for each assembly (cassette plus rails) to be used during the shot campaign in order to accommodate part-to-part variation in the manufacture of the assemblies. Positioning at TCC of the cassette and pointer, mounted on different sets of XRSA rails, has been shown to be accurate to 100  $\mu\text{m}$ , which is determined by the accuracy in the manufacture of the sets of rails rather than the limits of the alignment system at OMEGA. The pointer and stylus are removed before any actual target shots are performed. Additionally, the edge of the XRSA cassette has been given a chamfer that follows the beam intercept angle to provide additional beam-to-plate clearance in the cases where maximal fluence is required.

### III. FILTERS AND OPERATION

Figure 3 shows a face-on photograph of a six-sample cassette loaded with samples and filters before a shot. One can see in the picture that apertures through which the samples were exposed have different filter materials (Be, Al and Kapton in the picture); each of the six sample wells can have a unique soft-x-ray/UV filter material, or no filter at all. The six samples around the cassette's circumference are placed in 1.5" diameter receptacles machined into the 3/8" thick XRSA cassette. In every case, the majority of the specimen's face is exposed to the X-ray source, but a small part is left unexposed behind the material in the cassette head as a control region. One can see in the photograph that both 1" and 1.5" diameter specimens are being exposed; the 1 o'clock and 7 o'clock positions have spacer rings that surround the sample and center the 1" coupon in the 1.5" diameter receptacle.

Figure 4 shows an exploded view of the XRSA cassette and the hardware used to keep the samples positioned in their individual receptacles. A "pressure ring" surface machined into

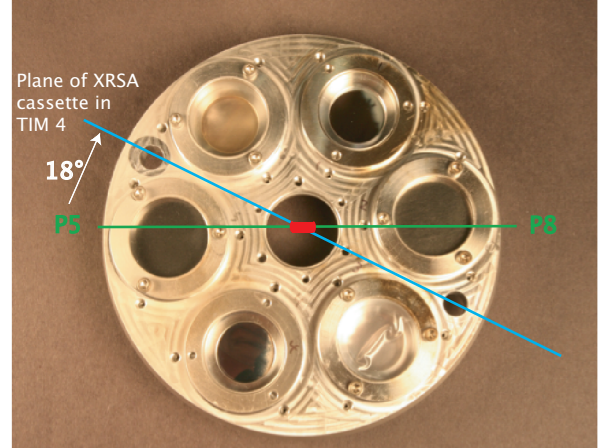


FIG. 3. (color online) Face-on view of the XRSA six-sample cassette used to test 1.0" and 1.5" diameter specimens with thin-film coatings on different substrates. The red cylinder drawn over the center of the cassette shows the orientation of a typical laser target along the P5-P8 axis in the OMEGA target chamber. The blue line at 18° to the P5-P8 axis represents the plane defined by the TIM-connect rails in Fig. 1.

the cassette head holds the sample in each of the sample wells. In order to let the sample under test have as much ability to flex and move as possible a 'line contact' between the pressure ring and the specimen is provided by a thin wire loop, see Fig. 4. A small break in the wire loop provides a pump-out path for the cassette before it is inserted into the high vacuum of the OMEGA target chamber. The samples are secured from behind by a sample-retainer plug that is attached by screws to the material of the cassette.

During setup of a cassette assembly, each sample is placed in a specific receptacle, indicated by a scribed number 1 to 6. The machined well allows a spacing of 5.5 mm from the sample's front surface to the back surface of the rear-most filter. The sample then has a compression coupon installed on top of it that

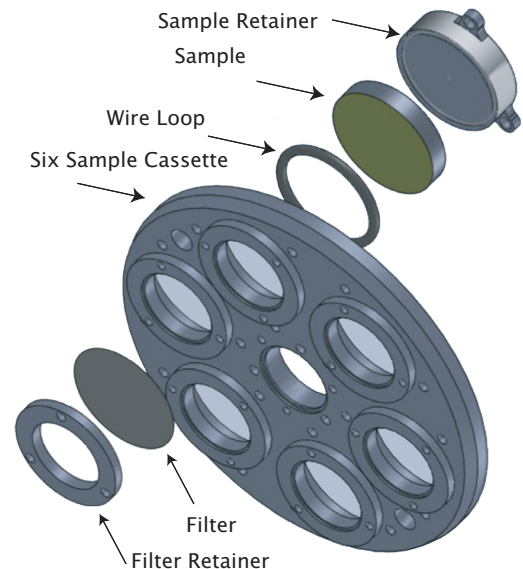


FIG. 4. (color online) XRSA cassette exploded view showing both the filter-assembly and sample-assembly hardware.

is torqued to 3 inch-Lb to allow conductive contact between samples and the cassette body. The next sample is then installed in its specified well until each well is filled with its specific specimen. Once the samples are installed, the cassette is turned over and filter materials are installed. The filters used recently vary from 25  $\mu\text{m}$  aluminum and plastic foils to 25  $\mu\text{m}$  thick beryllium disks. The disks are installed into the filter ring and an aluminum capture ring seats the filters into the cassette with 3 in-Lb torque to create a good contact surface junction. Once assembled, the cassette is photographed and installed on the rails to be inserted into the laser chamber for testing. Once shot, the cassette is retrieved and disassembled methodically to inspect damage and keep samples isolated for further investigation of results.

The XRSA cassette allows a sample to have four unique cuts on the x-ray spectral energy that it sees. This is accomplished by building up a quad stack of filters in front of each sample. For example, working from nearest the sample out towards the source, we would begin with a full 1.5" diameter circle of 25.4  $\mu\text{m}$  of Be, then we would overlay a 1.5" diameter half-circle of 25.4  $\mu\text{m}$  thick Al, followed by a 1.5" diameter half-circle of 25.4  $\mu\text{m}$  thick Ti. The build of the stack is illustrated graphically in Fig. 5, which also shows the cassette loaded with the quad filter stack for a shot. Additionally, in order to investigate a different spectral environment, we sometimes replace the 25.4  $\mu\text{m}$  of Ti with 8  $\mu\text{m}$  of Ni. In some experiments, to assess the dose received behind the quad-stack filters at each of the six sample positions in the XRSA cassette, we used three types of passive dosimetry: Fuji<sup>TM</sup> Image plate, FWT-60 radio chromatic (RC) film and HD-810 RC film.<sup>9</sup>

For the majority of shots on which the XRSA cassette has been run, the x-ray source target<sup>6,8</sup> has been cylindrical in design (see Fig. 3), which means there are two orientations of the cassette with respect to the source. In the first orientation, the face of the XRSA cassette looks at the laser-illuminated face of the target, this is the so-called laser entrance hole, or LEH, orientation. For the LEH orientation, the XRSA cassette is inside the converging cones of beam illuminating the target's face. As a result, the minimum standoff distance (SOD) for the cassette, typically 23 cm, is further back from the target compared to the other orientation, and the dose is (believed to be) uniform at each sample position due to the symmetry of the sample positions around the target's cylindrical axis. For the LEH orientation, the dose is actually higher onto the filters at the front of the cassette due to lack of attenuation of the lowest-energy x rays by the target material. The maximum value of fluence onto the filters in the LEH orientation (across all x-ray energies) is  $\approx 2 \text{ J/cm}^2$ . Alternatively, the cassette can be positioned so that the normal to the face of the XRSA cassette is perpendicular to the cylindrical target's axis, the so-called side-on view, as shown in Fig. 3. In this case, since it is outside the converging cone of laser beams, the cassette can approach a few cm closer to the source, typically as close as 20 cm. In this orientation, fluence onto the face of the XRSA cassette across all x-ray energies (before attenuation by filters if any are present) can be as high as  $0.4 - 0.5 \text{ J/cm}^2$ . For a typical OMEGA experiment, at the distance of closest approach for the side-on view, the fluence onto the six-sample cassette (before attenuation by filters) is typically  $\approx 0.25 \text{ J/cm}^2$ .

We have used the XRSA cassette in the side-on and LEH orientations to (1) assess dose uniformity received at the six sample positions, (2) to collect target debris on thick glass witness pieces, (3) to explore different filter schemes (metal meshes versus thin foils) that craft the x-ray fluence ultimately onto the samples and (4) to access the survivability of (stacks of) thin films coated onto metallic and ceramic substrates. We have also used XRSA cassettes with square receptacles to study the

interaction of solar-cell cover glasses and photovoltaic materials with the x-ray environments. We have carried out these tests at fluence levels that range from  $0.05 - 2 \text{ J/cm}^2$  onto the actual samples, with x-ray spectra that have unique energy distributions between 1 and 10 keV. Recently, we have added biased sets of Langmuir probes to the XRSA cassette to study the electron and ion components of the residual plasmas from our laser-driven x-ray sources at TCC.<sup>10</sup>

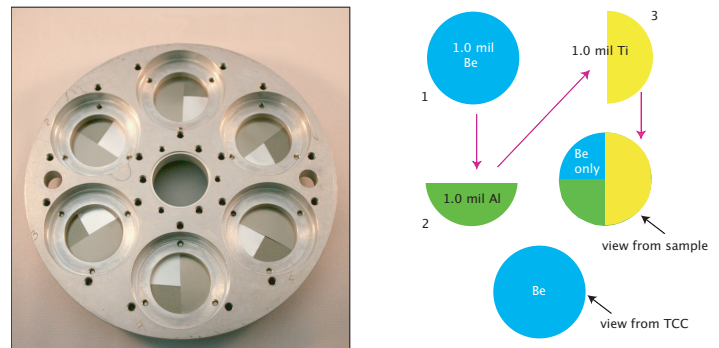


FIG. 5. (color online) (left) Picture looking into empty sample receptacles of a XRSA cassette with filters installed. (right) How quad stack of filters is assembled. The quad-stack configuration was used on shots that measured x-ray dose uniformity with radio-chromatic film and image plates, as well as on sample exposures.

## IV. SUMMARY

We have presented the design and operation of a cassette that can position six samples in the OMEGA target chamber for experiments during target shots. The cassette provides options for different sized samples up to 1.5" diameter round samples. The design also allows for multiple exposure areas over the face of individual samples; the cassette provides for multiple levels of filtration on a single sample, which allows dynamic range in experiments. Using mechanical pointers and facility imaging capability, the XRSA cassette can be positioned at a known sample-to-source standoff distance with an accuracy of better than a few hundred microns. This test cassette has been shown to be useful for experiments that study x-ray interaction with matter. This work was done under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and Defense Threat Reduction Agency IACRO no. 11-45511 "Research Program for X-Ray Experimentation Capability Using Laser Plasma Radiation Sources".

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